Behaviour of Gun Propellant to Ignitions of Different Intensities

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1. Introduction

In the case of large calibre ammunition, for example 105 mm and 120 mm, a uniform and accurate ignition of the propelling charge is of great importance.

A poor ignition may not only lead to a spread of the ballistic data (e.g. initial velocity of the projectile); the gas pressure inside the barrel may become so high, that the strenght of the barrel-material may be exceeded and hence the gun can be totally destroyed, even fatal casualities may happen.

It is known by experience, that different gun propellants react in different manner to poor ignition. Therefore it is desirable to have a small scale test at one´s disposal (which can be performed in the laboratory) by means of which it can be checked which gun propellant responds in a dangerous manner to a poor ignition.

Such a test should be not too expensive and nevertheless should yield reliable data.

In the following a test method is described which meets the above mentioned requirements.

2. Description of the test method

A sketch of the experimental set up is shown in figure 1. The propellant, with a mass of about 500 g is filled, with its bulk density, into a seamless steel tube, which is open at one side. The tube has a length of 350 mm, a wall thickness of approx. 5 mm and an inner diameter of 50,8 mm (2 inches). An igniter (fig. 2), also made of steel is fixed at the closed end of the tube. The tube then, with its open end is put onto a steel block. A quartz gage for measuring the pressure (up to 0.7GPa) is built into this steel block. When performing the test, a steel block with a mass of 18 kg is put onto the whole assembly.

For igniting the propellant we use quite normal black powder. The amount of black powder, which is filled into the igniter can be varied.

Up to 22 g black powder can be packed into the igniter.

The test output is the pressure in the steel tube (measured by the quartz) produced by the different igniter strengths.

The tubes rupture at pressures of approximately 0.08 GPa, therefore the burning of the propellant can be monitored, under normal circumstances, up to a pressure of 0.08 GPa.

3. Results

In figure 3 typical pressure time histories, which were recorded when performing the tests, are shown.

It can be seen, that in the case of a weak ignition (5 g black powder) a regular burning of the propellant occurs, when using stronger ignition conditions, the burning characterics significantly change, in other words the pressure rise time drastically decreases, and in some cases even pressures up to 0.7 GPa are produced. Though the steel tubes normally rupture at pressures of 0.08 GPa, the pressure rise time in this case, is so fast, that due to the inertia of the confinement, such high pressures can be attained.

4. Applicability of the method and discussion

In order to check the applicability of the test method we performed the test with several seven perforated gun propellants (see table 1).
Propellant 1, 2 and 3 were triple base propellants which chemical compositions were nearly the same, only the web sizes were sligthly different. The main difference between these propellants was the way how they were produced. Propellant 4 was a double base propellant and propellant 5 a single base propellant. All the propellants exhibited nearly the same interior ballistic data, which were determined in a closed vessel (see also table 1).
For ignition we used black powder charges of 5 g, 10 g, 15 g and 20 g. The relevant data for judging the response of the propellants to different ignition strengths are tabulated in table 2. As relevant data we took the maximum pressure, the pressure rise time and the maximum rate of the pressure rise ($\frac{dp}{dt}$).
When comparing the data it can be seen, that propellant 1 reacts most sensitively to the variation of the ignition strength, i.e. the rate of the pressure rise becomes greater when using a moderate ignition strength, whereas when looking at propellant 3 one can constate that very high pressure rise rates only occur, when using a very high ignition strength.

We think, that the very fast pressure rises, and hence the very high pressures, in the case of intense ignition, can be explained by assuming a fracture of the propellant grains.For theoretical calculations, using a gas dynamic model, yield similar pressure rises, when assuming that a part of the propelling charge (10 %-15 %) is fractured near the projectile base.

The fracturing of propellant grains, can be explained by a pressure gradient, produced by the ignition, which accelerates the charge downwords. At the steel block the motion is stopped and the grains can be fractured. The more intense the ignition, the greater will be the pressure gradient and the acceleration of grains and therefore the possibility of fracturing will rise.

The results, now, do not mean, in any way, that for example propellant 1 should not be used for constructing ammunition, but nevertheless the results show that, when using propellant 1 the ignition condition should be thoroughly investigated, in order to avoid a dangerous behaviour of the ammunition.

Furthermore it should be remarked, that at the present state of our investigations there exist no absolute, unambiguous criteria for judging the behaviour of the propellants, nevertheless the method can be used to compare different propellants, concering the behaviour to changes in the ignition conditions.

5. Summary

A small scale laboratory test is described by means of which it becomes possible to judge the behaviour of gun propellant to different ignition strength in the ammunition. The applicability of the test method could be shown.

Table 1

Interior ballistic data determined in a closed vessel. Loding Densitiy 0.1 $^{g}/cm^{3}$ (p_{max} in all cases approx. 0.1 MPa)

Propellant	1 triple base	2 triple base	3 triple base	4 double base	5 single base
L_D $[(Pa\ s)^{-1}]$	$0.11\ 10^{-5}$	$0.14\ 10^{-5}$	$0.11\ 10^{-5}$	$0.11\ 10^{-5}$	$0.19\ 10^{-5}$
r_p $[^{Pa}/\mu s]$	$0.52\ 10^{4}$	$0.62\ 10^{4}$	$0.55\ 10^{4}$	$0.58\ 10^{4}$	$0.61\ 10^{4}$
$(\frac{dp}{dt})$ $[^{Pa}/\mu s]$ p=0.08 GPa	$0.08\ 10^{5}$	$0.11\ 10^{5}$	$0.09\ 10^{5}$	$0.1\ 10^{5}$	$0.11\ 10^{5}$

L_D = dynamic vivacity =

$$= \left(\frac{dp}{dt}\right)_{0.5\ p_{max}} \cdot \frac{1}{0.5\ p_{max}^{2}}$$

r_p = pressure rise rate between 0.1 p_{max} and 0.9 p_{max}

Ignition	Propellant	No 1 triple base	No 2 triple base	No 3 triple base	No 4 double base	No 5 single base
5g black powder	P_{max} [GPa]	0.08	0.08	0.10	0.08	0.08
	$\left(\frac{dp}{dt}\right)_{max}$ $\left[\frac{MPa}{\mu s}\right]$	0.15	0.11	0.12	0.10	0.46
	tr [µs]	1050	1640	1250	1300	420
10g black powder	P_{max} [GPa]	0.075	0.08	0.07	0.08	0.08
	$\left(\frac{dp}{dt}\right)_{max}$ $\left[\frac{MPa}{\mu s}\right]$	0.22	0.13	0.11	0.10	0.57
	tr [µs]	500	1000	1250	1000	275
15g black powder	P_{max} [GPa]	0.11	0.08	0.07	0.08	0.28
	$\left(\frac{dp}{dt}\right)_{max}$ $\left[\frac{MPa}{\mu s}\right]$	0.80	0.50	0.18	0.26	10.0
	tr [µs]	150	300	940	400	20
20g black powder	P_{max} [GPa]	0.70	0.11	0.42	0.11	0.70
	$\left(\frac{dp}{dt}\right)_{max}$ $\left[\frac{MPa}{\mu s}\right]$	140	1.2	13	0.60	140
	tr [µs]	5	100	32	210	5

Table 2

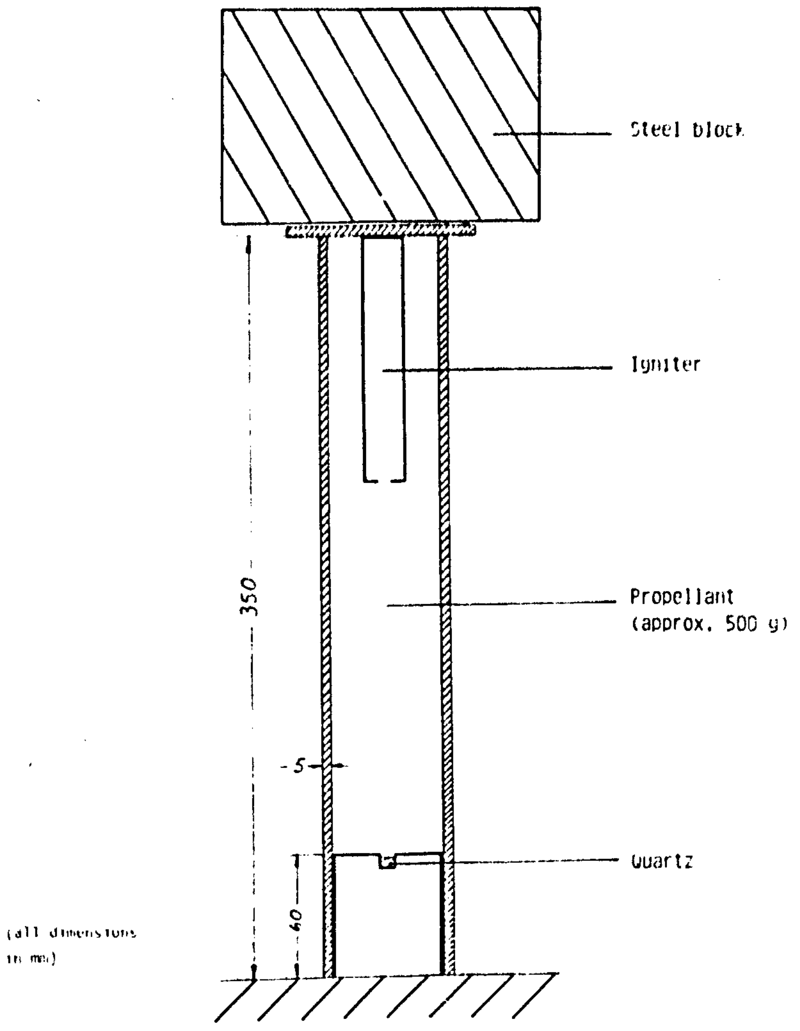

figure 1. Experimental Set up

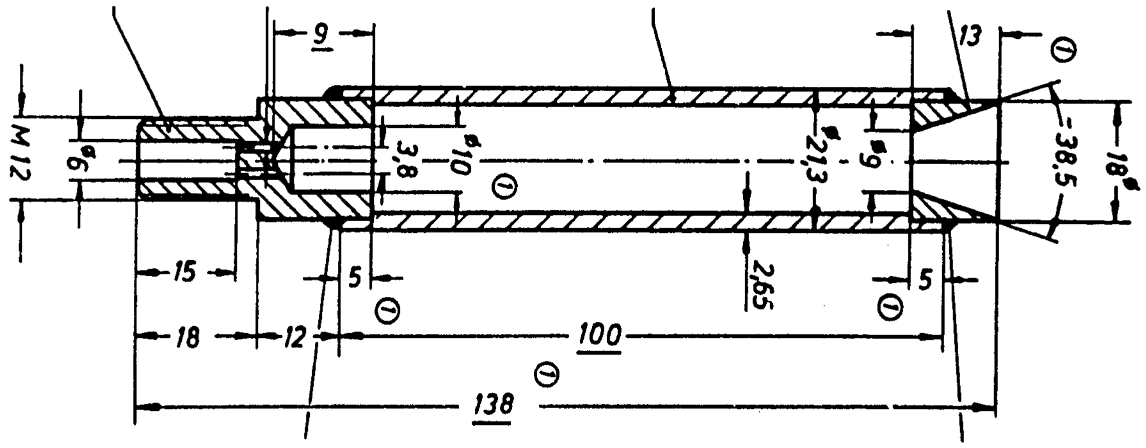

figure 2. Igniter

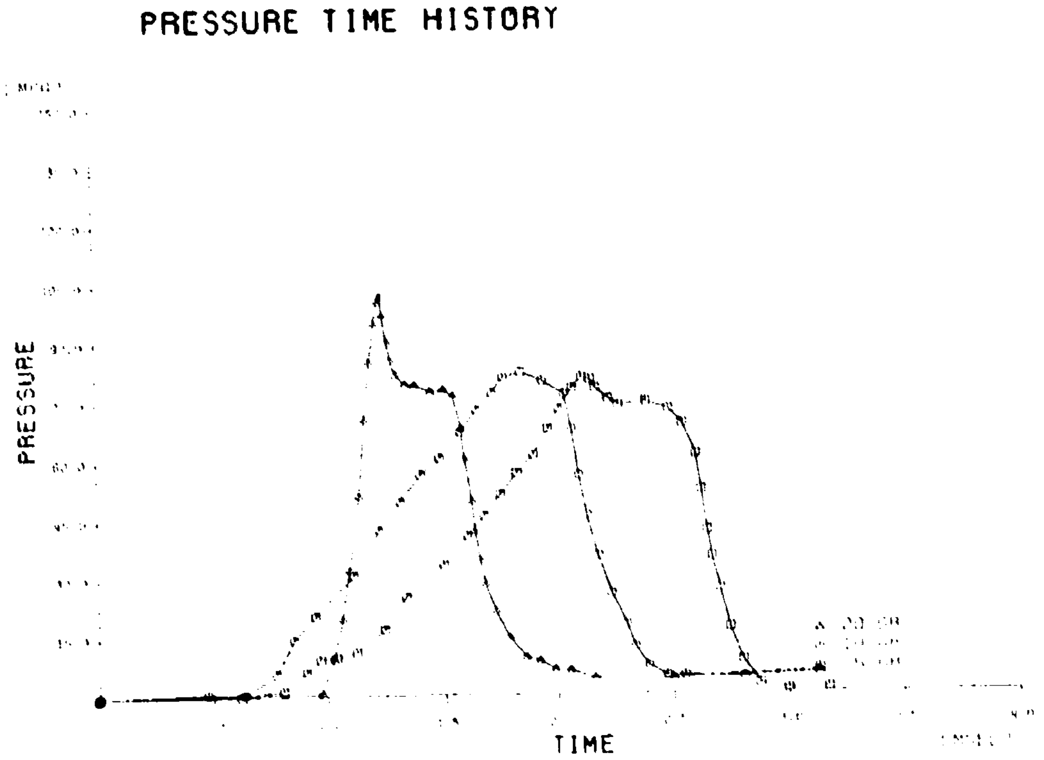

figure 3. Pressure Time History